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A Decision Support Process for Planning Air Operations

by

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Major, USAF

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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Abstract of
A DECISION SUPPORT PROCESS FOR PLANNING AIR OPERATIONS

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A DECISION SUPPORT PROCESS FOR PLANNING AIR OPERATIONS

CHAPTER I

INTRODUCTION

Desert Storm air operations are illustrative. How many sorties should be dedicated to attacking Scud missile launchers? Are airfield attack sorties worth the return on the effort? How many sorties should be used against the Republican Guard units? Should front line units also be attacked? If so, how many sorties should be used against them? What is the best use of the B-52s? How are the limited number of F-117 sorties best used?

Designing an air campaign is a daunting undertaking. The number of uses combat aircraft ~~can be put to~~ is virtually unlimited. Most aircraft are not limited by design to a single function and can be used for a variety of purposes. There are few limitations on the time and place any particular unit's aircraft can be employed. In order to make use of the inherent flexibility of aircraft, the planning of air operations is normally centralized. However, the complexity of the centralized planning of air operations poses a serious challenge to operational commanders.

This paper proposes a process that could serve as the basis for a decision support system. The goal of this process is to provide assistance to the Joint Force Commander and his Air Component Commander in planning air operations during major conflicts. The process is intended to help these

commanders make the best possible use of their air assets in achieving the strategic goals of the conflict. The process helps the operational commander structure his subjective judgments and make informed and logical choices. The process is not intended to provide an engineering like solution to the problem of designing an air campaign.

The proposed process is composed of three parts. The purpose of the first part is to determine what operational tasks should be performed. This determination is made through the use of a procedure referred to as the Strategy-to-Task process. The second part of the overall process is designed to establish priorities by using a decision aid called the Analytic Hierarchy Process. The final part of the process attempts to make an optimum allocation of resources to accomplish the tasks identified in the first part of the process and prioritized in the second part. Linear Programming is used to make the allocation.

CHAPTER II

DETERMINING OPERATIONAL TASKS: *THE STRATEGY TO TASK PROCESS*

Overview. The first step in the planning process being proposed is to determine the operational tasks that need to be accomplished. A particular conceptual framework will be proposed for use in making that determination. Many of the ideas used in that framework come from a process being proposed in the force planning community called *Strategy-to-Task*.

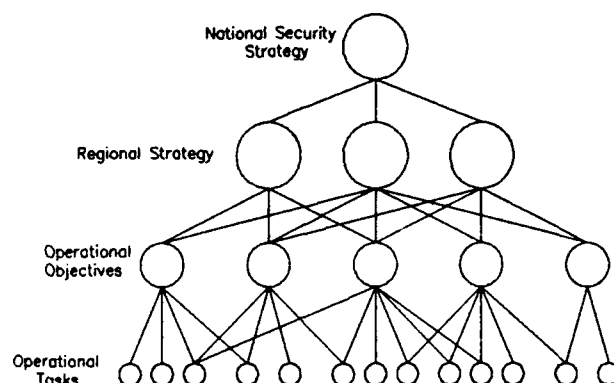
Virtually all writings on military planning emphasize the importance of establishing objectives for military operations. Additionally, the military establishment in the United States places great importance on aligning military objectives with the policy goals of the nation's political leadership. However, a systematic approach to achieving these goals that lends itself specifically to the follow-on demands of planning air operations has not been widely accepted. The Commander's Estimate of the Situation and Concept of Operations prescribed by the Joint Operational Planning System are certainly an aid in meeting these needs. However, while these documents provide a useful checklist for making major operational decisions, alone their utility in planing extended air operations is limited.

Over the past decade, there have been several efforts in the force planning community to meet this need for objective

based planning linked to policy. One of the most recent is called *Strategy-to-Task*.^{*} This methodology is based on a conceptual framework that structures the relationship of strategies down to tasks through four hierarchical levels. At the top level is the national security strategy. Next, in order to meet the requirements of that strategy, regional strategies are created. At the third level, a cluster of

Figure 1

Strategy-to-Task Levels



operational objectives that fulfill a particular regional strategy are created. At the bottom level, an operational concept for accomplishing each operational objective is

^{*} There have been a variety of efforts made under the general rubric "Strategy-to-Task". Perhaps best known is the work of Glenn Kent of Rand. However, the conception of the Strategy-to-Task approach expressed here represents this writer's opinion.

devised and used to generate a cluster of required operational tasks. Figure 1 illustrates this hierarchial structure.

National Security Strategy. At the top level of the hierarchy is the National Security Strategy. Meeting the needs of this strategy is the ultimate objective of the military operations planned in the bottom levels of the hierarchy. There are elements of this strategy that are forged on the basis of enduring goals and values of American culture and, consequently, tends to be very stable over time. Elements of this standing national security strategy address various global and regional conflict scenarios. However, as events lead towards a particular conflict, the nations political leadership -- with advice from the Joint Chiefs of Staff -- will be forging a particular strategy for dealing with that particular situation. For the purposes of this operationally oriented application of the Strategy-to-Task process, this scenario specific strategy is at the top level of the strategy-to-task hierarchy.

The reaction of various domestic political power centers and the reaction of allies and third party nations to unfolding events will strongly influence the strategy the President and his advisors device. Additionally, the President's strategy will consider the intensity and duration of public support he can expect and how that support can best be facilitated.¹ In short, in addition to being a rational planning process, policy and strategy creation is politics.²

Another aspect of the strategy is its long term outlook. The President must look ahead to his long term foreign policy goals and to how the current conflict is going to change the political environment. Consequently, some aspects of the strategy may not appear to be an entirely logical response to the immediate circumstances that precipitated hostilities. However, the strategy must be considered as part of a continuing foreign policy that looks beyond the outcome of the immediate conflict.

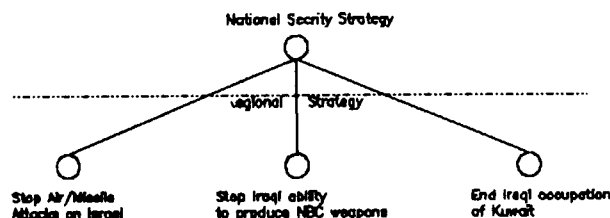
Out of this process a strategy based on compromise and accommodation will emerge. Due to the conflicting views and interests of various domestic political entities and allied nations, that strategy will in all likelihood be stated in vague and general terms. It is always possible that a more explicit statement of the strategy will be available through classified communications. Nonetheless, precisely because the strategy is likely to be politically sensitive, there will be a high probability that all essential aspects of the strategy will eventually be leaked to the news media. Therefore, there is generally a strong motivation for the political leadership to use guarded language.³

The nature of the strategy just described means a consistent structure or the use of specific terminology cannot be prescribed. However, three key considerations should be inherent in any national security strategy. First, is a sense of what conditions should exist at the end of the conflict.

Second, is a sense of what costs the political leadership is willing to pay to achieve those conditions. Third, is an indication of what levels of risk are tolerable. Additionally, there may be special constraints on military activity based on specific domestic or international political considerations.

Regional Strategy. Responsibility for establishing a more concrete military strategy based on the strategic aims of the national leadership will generally fall largely to the Theater Commander. Given the political realities described earlier, the Theater Commander may have to develop this strategy on the basis of his own interpretation of a fairly amorphous national strategy. His goal is to provide a general plan for accomplishing the goals of the national strategy within that strategy's cost and risk bounds. The strategy-to-

Figure 2
Regional Strategy Goals



task hierarchy is based on increasing specificity as the hierarchy branches out. The central role of the regional strategy in this process is to provide a clear statement of military aims against a specific military threat. The goals of the regional strategy will still be very broad in scope, but they should be stated clearly and distinctly delineated. The regional strategy level of the strategy-to-task hierarchy should provide a transition between a relatively vague national security strategy and a relatively specific set of operational objectives. Figure 2 shows an example of how this level might look in a hypothetical hierarchy.*

Operational Objectives. Establishing a set of specific operational objectives that are required to fulfill the regional strategy is the goal of this step in the strategy-to-task system. This requirement generally conforms with the planning guidance in the Joint Operational Planning System. However, the emphasis in this approach is not on a singular mission statement or selecting a single course of action that solves a particular military problem. Rather, the goal is to consider the whole of a potentially long and complex conflict and identify a set of several objectives that will in combination fulfill a specific goal of the regional strategy.

* The examples shown throughout this paper are only meant to illustrate the process. They do not represent an effort to actually execute the process.

The operational commander will be creating a method of achieving the goals of the regional strategy and in most cases there will be many alternative approaches to solving that problem. As a consequence, the process of determining the operational objectives is largely a creative process in which subjective choices are made. There will often be a temptation to address the problem by creating objectives that cover every possible means of executing the regional strategy. However, in the absence of an overwhelming advantage over the enemy and virtually unconstrained resources, the strategy will generally be better served by committing to one or a few approaches to achieving the requirements of the strategy.

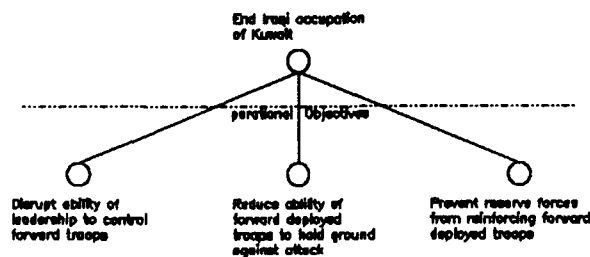
The operational objectives should be stated in language that clearly states in plain english what is to be accomplished. The precise wording of the statement of the objective should be made with extreme care. While there is nothing to be gained from an excessively verbose statement of the objective, the greater danger is a laconism that leaves the precise meaning of the objective a matter of interpretation. In particular, military jargon or phrases from doctrine that attempt to encompass complex and potentially controversial concepts should be avoided.

Operational objectives should apply to the total force. There is often a tendency to state objectives in terms of the functional tasks of the various bureaucratic components of the force. It may very well turn out that only one component of

the force will be tasked against a particular objective, but the objectives should not be designed or structured with that outcome in mind.

The process of determining the scope of each objective must take place with consideration for the context of the total strategy-to-task hierarchy that is being created. When stating the operational objectives there is no necessity to make a comprehensive statement of all that is encompassed by that objective. The lower levels of the hierarchy will delineate the actions that are required to accomplish the upper level operational objectives in detail. It is important that each operational objective contribute directly to accomplishment of the regional strategy and not be just a

Figure 3
Example Operational Objectives



means towards accomplishing one of the other operational objectives. While it may not be possible to avoid all interdependence between operational objectives, to the greatest degree possible each operational objective should stand alone on its own merits. If several operational objectives together represent a sequence of events that must take place to reach the desired end, then they should be at a lower level of the hierarchy and a statement of that final desired end should be made the operational objective. Figure 3 shows an example of how this level of a hypothetical hierarchy might look.

Operational Tasks. The bottom levels of the hierarchy contain the operational tasks. These are the activities that must be accomplished in order to achieve the operational objectives. It is possible, indeed it is likely, that a particular operational task will contribute to the accomplishment of more than one operational objective. However, the procedures for deriving the operational tasks should be a top down based system that develops a particular operational concept for accomplishing each operational objective.

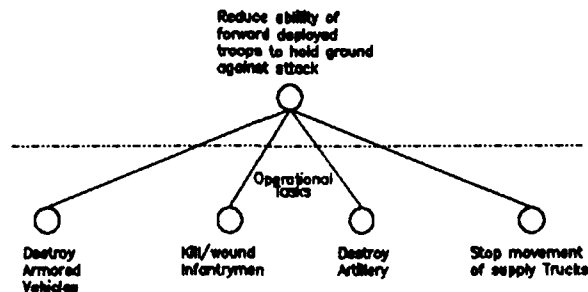
Each operational concept will usually entail the execution of several operational tasks. If the list of operational tasks required to accomplish a particular objective becomes very long, then those operational tasks should be grouped into several clusters by introducing a

sub-objective level of the hierarchy between the operational objective level and the operational task level.

When creating operational tasks (or sub-objectives), the same concerns apply as when creating operational objectives. The language used to describe the tasks should be selected with great care and should avoid jargon from service doctrines. Additionally, the temptation to structure the tasks to align with organizational structures should be resisted.

To an even greater degree than at the operational objectives level, the selection of operational tasks is a creative process in which one of a nearly infinite number of potential operational concepts for achieving the objective is

Figure 4
Example Operational Tasks



selected. The fact that a particular task was omitted does not necessary imply that it is not a valid alternative, rather only that better alternatives were judged to make it unnecessary. On the other hand, the commander does have the option to include redundant tasks if he feels pursuing parallel approaches is necessary due to the uncertainties involved. Figure 4 shows an example of how this level of a hypothetical hierarchy might look.

CHAPTER III

ESTABLISHING PRIORITIES: *THE ANALYTIC HIERARCHY PROCESS*

Overview. Having determined what tasks need to be undertaken, the next step in the proposed decision support system is to establish the relative priority of each task. In this case establishing priorities means more than providing a rank order listing of the tasks. The goal of this process is to establish the relative importance of each task compared to the others using a ratio scale.

The mechanism for measuring each tasks importance will be the *Analytic Hierarchy Process* (AHP). AHP is a theory of measurement designed to aid in the decision making process. AHP begins by decomposing a complex problem into a hierarchic structure (as this process has done through the Strategy-to-Task method.) It then makes paired comparisons using a scale of relative magnitudes. Next, the priorities within each cluster within the hierarchy are calculated on the basis of these comparisons. Finally, an overall scale of priorities across the entire hierarchy is synthesized. In this chapter, AHP will be applied to that Strategy-to-Task hierarchy using these last three steps.

Paired comparisons. The first step in this stage of the proposed planning system is to collect the judgments of the commander on the relative importance of each item in the strategy-to-task hierarchy. This is done by having him make a

comparison of each possible paired combination of items within each cluster of items in the hierarchy. The use of pairwise comparisons allows the decision maker to focus his judgement on a series of direct comparisons between the relative importance of two items. For any cluster of n items there will be $(n^2-n)/2$ paired comparisons. Figure 5 shows an example of pairwise comparisons from part of a strategy-to-task hierarchy.

In making the pairwise comparison a scale of relative magnitudes expressed in dominance units is used. Figure 5 shows the scale. The scale is based on research by psychologist on the native ability of people to discriminate magnitudes in stimulus.⁴ In soliciting the commander's judgments a questionnaire of the form shown in figure 5 would be used.

Calculating cluster priorities. The next step in the proposed planning system is to use the AHP to generate the relative priority of the goals, objectives, or tasks within a cluster in the hierarchy. An example of the calculation of cluster priorities is illustrated in figure 6. The process begins by placing the values from the commander's questionnaire into a matrix. The matrix is composed of both the relative importance of A to B and B to A, each being the reciprocal of the other. Once the matrix is constructed, the principle eigenvector of the matrix is calculated and then normalized such that the sum of the vector is one. A precise

FIGURE 5

Analytic Hierarchy Process Questionnaire

Compare each pair of tasks on the basis of how much completion of each task would reduce the ability of forward deployed enemy troops to hold ground against attack by our troops.

- Task 1: Destroy Armored Vehicles
 Task 2: Kill/wound Infantrymen
 Task 3: Destroy Artillery
 Task 4: Stop Movement of Supply Trucks

	absolute	very strong	strong	weak	EVEN		weak	strong	very strong	absolute								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
AFV			X															INFANTRY
AFV							X											ARTILLERY
AFV					X													TRUCKS
INFANTRY											X							ARTILLERY
INFANTRY									X									TRUCKS
ARTILLERY				X														TRUCKS

Intensity of Importance
 on an Absolute Scale

Scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement slightly favor one activity over another
5	Essential or strong importance	Experience and judgement strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

Source: Thomas L. Saaty, *The Analytic Hierarchy Process* (Pittsburgh: University of Pittsburgh, 1988), p. 54

FIGURE 6

Example of AHP Calculation Results

	AFV	INF.	ARTY	TRUCK
AFV	1.00	7.00	3.00	5.00
INF.	0.14	1.00	0.33	1.00
ARTY	0.33	3.00	1.00	6.00
TRUCK	0.20	1.00	0.17	1.00

Eigenvector	Wiegths
3.20	.57
0.47	.08
1.57	.28
0.43	.08

Eigenvalue	4.15
Consistency Index	0.05
Consistency Ratio	0.05

FIGURE 7

Random Index

1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

Source: Saaty, p. 21

calculation of the eigenvector is rather difficult without the use of special computer programming. However, a close approximation can be calculated relatively easily on a personal computer by taking the n th root of the product of each row in a matrix with n elements. The values in the vector are then normalized in order to provide the relative weight of each item on a scale from zero to one.

When making the paired comparisons the commander is under no explicit requirement to be consistent. For example: if he states that objective A is three times more important than objective B and objective A is six times more important than objective C, then it follows logically that he should have ranked objective C is twice as important as objective B. However, AHP is based on the expectation that he will, in fact, not render perfectly consistent judgments. Research indicates that this "intransitivity" is a natural phenomenon in human preferences.⁵ Up to a point such intransitivity should not be considered an error, rather it should be considered an additional piece of data about a persons preferences.

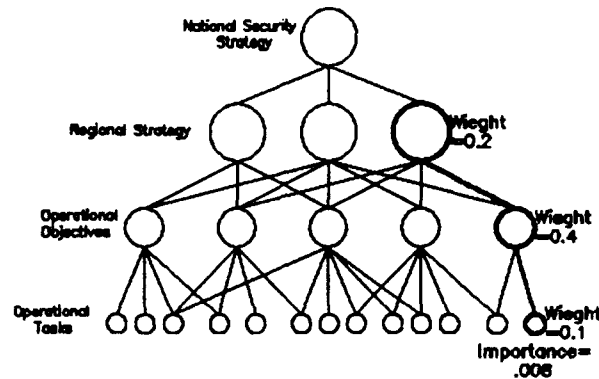
To measure the degree of inconsistency in the commander's judgments the following process is used. First, the maximum or principle eigenvalue is calculated. Again while precise calculation is complex, this value can be closely approximated with reasonable ease. To do so, multiply the solution eigenvector and the comparison matrix. Next, divide each

component of the resulting vector by the corresponding component of the solution vector. Finally, find the mean of the resulting vector. This value approximates the maximum eigenvalue. The next step is to calculate the consistency index (C.I.) by the formula $(\delta_{\max} - n) / (n - 1)$ where δ_{\max} is the maximum eigenvalue. The C.I. can then be compared to the table of consistency indexes for a random matrix of n dimensions (Figure 7.) The ratio of the C.I. to the random index (R.I.) of the same size matrix gives the consistency ratio (C.R.).

A C.R. of 0.1 or less is generally considered acceptable. If the commander's questionnaire exhibits more inconsistency than this, then he needs to reconsider his responses. His staff can aid him by pointing out the major cases of intransitivity. On the other hand, C.R. values less than 0.1 are not a problem and the calculations above should adequately capture the additional information provided by this inconsistency.

Calculating overall priorities. The final step is to calculate an overall scale of priorities across the entire hierarchy. For the sake of clarity some terminology will now be introduced. Each of the strategic goals, operational objectives, and operational tasks that compose the hierarchy will be referred to as a *node* in the hierarchy. The priority values assigned to each node will be referred to as the *weight* of that node. Note that the sum of the weights for any one

Figure 8
Calculating Importance from Weights



cluster of nodes is equal to one. The final purpose of this section is to calculate what will be referred to as the bottom level importance of each operational task. This is accomplished by taking all the individual operational tasks that compose the bottom level of the hierarchy and assigning each of them an importance value that is part of a single ratio scale for all operational tasks. The importance of all operational tasks together will equal one. Each operational task's importance is calculated by taking the product of the weight of the operational task and all the weights of the nodes in a direct line above the task in the hierarchy (as illustrated in figure 8.) Finally, where operational task are duplicated, their bottom level importance values are summed to get a single final importance for each operational task.

CHAPTER IV

ALLOCATING RESOURCES: A LINEAR PROGRAMMING METHOD

Overview. Having determined what the relative importance of each operational task is, the next step in the proposed decision support system is to make the optimum allocation of resources to each task. In addition to the importance of each task, this allocation must consider the resources available to perform the tasks and the relative effectiveness of the force's ability to perform each task. The method proposed for making the allocation is a mathematical optimization technique called Linear Programming (LP). In particular a formulation and solution of the allocation problem using the simplex method of solving LP problems will be proposed. LP solutions to all but the simplest problems require special computer software. A variety of commercial LP software programs are readily available, however the size of the problem in planning air operations will require one of the more advanced packages. The illustration of the method used here will focus strictly on those operational tasks in an air campaign involving the attack of ground targets. However, the same basic principles can be applied to a wider variety of operational task.

Formulation of the problem. When executing an air campaign the operational commanders will strive to destroy the largest number of the most important targets. The solution must take into account the fact that at any one point in time

there will be a limited number of aircraft and munitions available. The problem the commander faces is how to allocate those aircraft and munitions to the various targets. The solution should take advantage of the relative strengths and weaknesses of each type of aircraft and munitions against each type of target. One other factor that must be considered is the likely cost in aircraft losses from the various possible allocation strategies. As an example, an optimum allocation of three aircraft types and four types of munitions against six tasks will be made.

Decision variables. The first step in the LP process is to determine all the factors that will control the solution to the problem. Figure 9 shows the basic factors that will effect the solution to the example problem. One of the advantages of LP is that a virtually unlimited number of factors can be used to constrain the outcome. For the purposes of this example, however, only the most fundamental factors are considered. It is entirely possible to add many others.

Most of the information, such as the quantities of sorties and munitions available, is fairly straightforward. However, the effectiveness factor requires further elaboration. What is required is some measure of how much of the overall task is accomplished by a single sortie. For example, if the task is to destroy Armored Fighting Vehicles (AFV), then a measure of how many AFVs will be destroyed, on

FIGURE 9

Decision Variables

	Sqdns	Sortie Rate	Sorties
AIRCRAFT			
1 F-16	6	2.2	317
2 F-15E	2	2.0	96
3 F-117	1	1.8	43

	Quantity	Importance	Tgt Value
TARGETS			
1 C2 Ctr	40	.15	.0038
2 Scud	35	.20	.0057
3 Depot	75	.10	.0013
4 AFV	350	.35	.0010
5 Truck	800	.05	.0001
6 Bridge	26	.15	.0058

	Inventory
MUNITION	
1 MK-84	500
2 CBU-87	300
3 CBU-24	100

	Aircraft	Munition	Target	Effect-iveness	Attrition	T.V.\Sortie
X(1)	F-117	2 GBU-24	Bridge	.95	.001	.005481
X(2)	F-117	2 GBU-24	C2 Ctr	.80	.001	.003000
X(3)	F-117	2 GBU-24	Scud	.80	.001	.004571
X(4)	F-117	2 MK-84	AFV	.20	.001	.000200
X(5)	F-117	2 MK-84	Bridge	.50	.001	.002885
X(6)	F-117	2 MK-84	C2 Ctr	.15	.001	.000563
X(7)	F-117	2 MK-84	Depot	.20	.001	.000267
X(8)	F-117	2 MK-84	Scud	.55	.001	.003143
X(9)	F-117	2 MK-84	Truck	.30	.001	.000019
X(10)	F-15E	2 AGM-65	AFV	.85	.010	.000850
X(11)	F-15E	2 AGM-65	C2 Ctr	.60	.009	.002250
X(12)	F-15E	2 AGM-65	Depot	.10	.008	.000133
X(13)	F-15E	2 AGM-65	Scud	.80	.009	.004571
X(14)	F-15E	2 AGM-65	Truck	.55	.009	.000034
X(15)	F-15E	8 CBU-87	AFV	.45	.011	.000450
X(16)	F-15E	8 CBU-87	Scud	.75	.008	.004286
X(17)	F-15E	8 CBU-87	Truck	.65	.007	.000041
X(18)	F-15E	2 GBU-24	Bridge	.90	.004	.005192
X(19)	F-15E	2 GBU-24	C2 Ctr	.75	.004	.002813
X(20)	F-15E	2 GBU-24	Scud	.80	.003	.004571
X(21)	F-15E	4 MK-84	AFV	.25	.010	.000250
X(22)	F-15E	4 MK-84	Bridge	.55	.009	.003173
X(23)	F-15E	4 MK-84	C2 Ctr	.25	.008	.000938
X(24)	F-15E	4 MK-84	Depot	.35	.006	.000467
X(25)	F-15E	4 MK-84	Scud	.50	.007	.002857
X(26)	F-15E	4 MK-84	Truck	.40	.008	.000025
X(27)	F-16	2 AGM-65	AFV	.70	.012	.000700
X(28)	F-16	2 AGM-65	C2 Ctr	.50	.010	.001875
X(29)	F-16	2 AGM-65	Depot	.07	.009	.000093
X(30)	F-16	2 AGM-65	Scud	.70	.010	.004000
X(31)	F-16	2 AGM-65	Truck	.45	.010	.000028
X(32)	F-16	4 CBU-87	AFV	.40	.009	.000400
X(33)	F-16	4 CBU-87	Scud	.65	.006	.003714
X(34)	F-16	4 CBU-87	Truck	.50	.005	.000031
X(35)	F-16	2 MK-84	AFV	.30	.008	.000300
X(36)	F-16	2 MK-84	Bridge	.60	.007	.003462
X(37)	F-16	2 MK-84	C2 Ctr	.20	.006	.000750
X(38)	F-16	2 MK-84	Depot	.20	.004	.000267
X(39)	F-16	2 MK-84	Scud	.50	.005	.002857
X(40)	F-16	2 MK-84	Truck	.35	.006	.000022

average, for each sortie flown is needed. This calculation can be made to varying degrees on the basis of objective data from weapons testing, past experience, and so forth. However, it generally will also require some subjective judgments. For example, the effects of such factors as camouflage and deception on target acquisition. In the early stages of a conflict the factors used will be based on estimates made during peacetime planning. As a conflict progresses these numbers can be refined on the basis of experience. Efforts to make this effectiveness number as accurate as possible on the basis of objective measures can become extremely complex. On the other hand, the AHP process just described to estimate task importance can be used to elicit expert judgments and compute a purely subjective estimate of effectiveness. For the purposes of this example, arbitrary effectiveness values are used for purely illustrative purposes.

Objective Function. The next step in the process is to construct an objective function. This is essentially an equation that represents how the decision variables effect the goal of the decision process.

In this case the goal will be to maximize the target value destroyed. The target value will be defined as the importance of an operational task divided the quantity of individual targets included in that task. This formulation is used because it is more intuitive to think of effectiveness in terms of the number of individual targets neutralized than it

is to think in terms of the portion of all targets within a task neutralized. However, it is important for the users of the process to keep in mind that the real goal of the process is to accomplish a task and not to merely destroy as many targets as possible.

The variables in this equation are the number of sorties allocated to each possible aircraft/munition/target combination. The constants are the expected fractional target value neutralized per sortie flown. The number of variables in the objective function can easily become very large. Consequently, when it is obvious that particular aircraft/target/munitions combinations are impossible or impractical, they should be eliminated before being placed in the LP objective function.

Constraints. The next step in the LP technique is to compose equations that represent constraints on the solution to the problem. Some of the obvious constraints are the number of sorties and munitions available. Another is the number of acceptable aircraft losses. The Joint Force Commander or the Air Component Commander may apply other constraints. For example they may feel that some level of effort must be applied to certain tasks even if that represents a sub-optimal course of action. In that case they could specify that no less than a certain percentage of the total effort be applied to those particular tasks.

Figure 10

Results of LP allocation

Overall, 65% of the value of the total target base is destroyed. 210 of the original 350 enemy AFVs remain, 68 of 75 Supply Depots remain, and none of the enemy's 800 trucks were destroyed. All available aircraft sorties and munitions are used up in the effort. 3-4 aircraft are expected to be lost.

F-117 usage is:

all - GBU-24s vs C2 Centers

F-15E usage is:

70 - AGM-65 vs AFV

7 - GBU-24 vs Centers

19 - MK-84s vs Supply Depots

F-16 usage is:

29 - AGM-65 vs AFV

75 - CBU-87 vs AFV

99 - MK-84 vs AFV

43 - MK-84 vs Bridges

70 - MK-84 vs Scud Missiles

Solutions. Figure 10 shows the results of the example problem.* The solution shows which aircraft sorties should be loaded with which munitions and what task those aircraft/munition combinations should be applied against. The solution will also produce a measure of total mission accomplishment as represented by the goal of the objective function. In this case that means the percentage of the total target value neutralized. This number should be approached with caution. The purpose of this decision support system is to help the commander determine how to best use his forces to accomplish the aims of the regional strategy. In this case that is represented by the sortie and munitions allocations. For the purposes of estimating the optimum allocation relative

* The solution was calculated by using the Storn computer program.

measures are sufficient. However, this process is not designed to make an accurate measurement of mission accomplishment in absolute terms. It would be highly misleading to report to the Theater Commander that tomorrow's missions will destroy a certain percentage of the target base on the basis of these calculations.

Sensitivity Analysis. The commander's staff will want to do some sensitivity analysis on the solution to see to what degree the various resource levels and other constraints were driving the solution. In this process factors may come to light that indicate ways to provide a better overall level of mission accomplishment. The analysis may also reveal how particular assumptions or measurement techniques are effecting the solution. This information may cause the staff to recommend adjustments to the allocation or, when informed of these effects, the commander may wish to adjust the allocation intuitively. Most LP software packages include aids to sensitivity analysis.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The broad concepts of the decision support process discussed in this paper can be used as the foundation for implementing an actual system to be used as an aid in planning the conduct of air operations in a major conflict. This system would not provide a perfectly engineered solution to the design of an air campaign. The system is based entirely on subjective judgments and the use of mathematical techniques does not change the fact that the results of the system can be no better than the quality of those subjective judgments. Nonetheless, this system could prove to be a valuable aid to operational commanders in what is a very complex decision process. The system helps by providing a systematic approach to organizing the problem and it helps in making choices that are informed and logical.

A detailed plan for implementing the proposed decision support system would require a major staff effort and at some point contractor support would probably be needed to help determine specific approaches to the computer hardware and software elements of the system. However, before beginning development of the system a determination needs to be made on whether to operate the system out of the Joint Force Commander's staff or from the Air Component Commander's staff. In either case, the top levels of the Strategy-to-Task

hierarchy and the pairwise comparison questionnaires relative to those levels will require either input or approval from the Joint Force Commander. The decision on where to host the system would indicate where to start the actual development process.

It is entirely possible to turn this process into an extraordinarily complex system. However, initial efforts are probably better advised to aim at a relatively simple system. Adding inputs for numerous objective measures effecting air operations could greatly increase the complexity of the system. It is recommended that the focus be kept on support to intuitive decision making. This writer would recommend a modest effort to provide a basic decision support system based on this process for use by the Joint Force and Air Component Commanders in planning air campaigns.

NOTES

1. Morton H. Halperin, *Bureaucratic Politics and Foreign Policy* (Washington: The Brookings Institution, 1974), pp. 76-83.
2. Roger Hilsman, "Policy-Making Is Politics," James N. Rosenau, ed., *International Politics and Foreign Policy* (New York: The Free Press, 1969), pp. 232-238.
3. Halperin, pp. 192-195
4. Thomas L. Saaty, *The Analytic Hierarchy Process* (Pittsburg: University of Pittsburg, 1988), pp. 53-54.
5. Saaty, p. 52.

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